Kirchhoff's Current Rule

The "current law" states that at a junction all the currents should add up.

$$I_3 = I_1 + I_2 \quad \text{or} \quad I_1 + I_2 - I_3 = 0$$

Current towards a point is designated as positive.

Current away from a point is negative.

Current Multipliers

There are some important **multipliers** for current or other electrical quantities:

1 microamp (1 µA) = 1×10^{-6} A

1 milliamp (mA) = 1×10^{-3} A

Also remember to make sure you work out current in Amps and time in seconds in your final answers!

Kirchhoff's Voltage Law

For any complete loop of a circuit, the sum of the e.m.f.s equal the sum of potential drops round the loop.

A cell is a positive e.m.f. a resistance is a negative.

$$\varepsilon = V_1 + V_2 + \ldots$$

PD Series or Parallel

In a series circuit the energy is shared between components according to the Kirchoff law.

In a parallel circuit each branch is at the PD of the power supply. Then on that branch the PD is shared as with a series circuit.

Current Series or Parallel

Current is a series circuit is the same everywhere.

Current in a parallel circuit splits at branches according to resistance and recombines at a later junction.

Ammeters

Ammeters count the flow of electrons or Cs^{-1} in a circuit.

They have a very low resistance and only take a very tiny current to make them work.

This is why we place them in series with components.

Voltmeters

A voltmeter (can be an oscilloscope as well) is a very high resistance meter and simply compares one side of a component to another.

It tells us the energy potential difference or PD. This is measured in volts or JC^{-1}.

This is why they are placed in parallel with components

Symbols

You should know the symbols for al the basic items such as… filament lamp, resistors of every type, battery, cell, LDR, Diode, LED, Thermistor, heater, motor, A,V, Internal resistance inside a cell, AC supply etc..

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EMF - ε

This is the electromotive force or push produced by an energy source… $\varepsilon = E/Q$. It is measured in volts (JC^{-1})

The EMF is also the theoretical value that can be created by a cell but not the actual P.D. across the terminals that actually occurs when you start to draw current.

PD Across Terminals

When you actually start to draw current from an energy source the emf drops the more you draw current. We lose energy in the power supply.

Hence e is only theoretical and we actually get a PD less than this for our real circuit.

ε

Internal Resistance

If we think of the power source of having an internal resistance to current flow the sum of all the emf in the circuit..

$$\varepsilon = V_{int} + V_{load}$$

$$\varepsilon = Ir_{int} + IR_{load}$$

$$\varepsilon = I(r_{int} + R_{load})$$

$$\varepsilon - Ir_{int} = V_{load}$$

IR Graphing 1

$$V_{load} = \varepsilon - Ir$$

This shows us that when we make a simple circuit and then draw more current through a reduced resistance the internal resistance consumes more of the ε when the current is higher.

Hence a graph shows intercept as "ε" and the gradient as "r".

Int Res Series and Parallel

If you have cells in series their internal resistance adds up to be…

Series -> $r_T = r_1 + r_2 + ...$

Parallel -> $1/r_T = 1/r_1 + 1/r_2 +..$

If graphing the circuit you would need to treat the gradient as r_T.

Power and EMF

We can also think about the situation for internal resistance as a power transfer and then rearrange our equations to this…..

$P_{circuit} = P_{cell} + P_{load}$

$P = \varepsilon I = I^2r + I^2R$

ε

Load Matching

If we consider that $P = I^2R = I^2(R+r)$ then we can plot a complex equation curve to look at how Power varies when you compare the internal resistance to the load.

We should know that when r=R i.e. 4Ω = 4 Ω then the maximum power will be delivered to the circuit.

IR Graphing 2

We can think of our formula in the way of a straight line graph….

$V_{load} = (-r)I + \varepsilon$

$y = (m)x + c$

$V_{load} = y$

$-r = \text{gradient}$

$I = x$

$\varepsilon = c$

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Series Resistance

When you connect a resistor in series with another the current flows through both.

This **increases** the resistance overall. The total resistance of a branch is easy to find.

$$R_T = R_1 + R_2 + ...$$

$$15\ \Omega = 10\ \Omega + 5\Omega$$

Parallel Resistance

When you connect a resistor in parallel with another the current flows through both. This **decreases** the resistance overall as there are many branches. The total resistance of a branch is harder to find.

$$1/R_T = 1/R_1 + 1/R_2 + ...$$

$$1/R_T = 3/10\ \Omega = 1/10\ \Omega + 1/5\Omega =$$

$$R_T = 10\ \Omega /3 = 3.3\ \Omega$$

Resistance Heating

Charge carriers transfer kinetic energy to positive ions through repeated collisions. The pd across the material then provides an accelerating force to the charge carrier which then collides with another positive ion. The heating effect is energy delivered or energy delivered per second…

$$P=VI,\ P = I^2R = P\ V^2/R$$

Working out circuits

- Combine the resistances on each branch using parallel or series equations.
- Work out the current in each branch.
- Work out the p.d. across branch.
- Work out the energy dropped across a component.

Net EMF’s

If you have a circuit with two sources of emf in series they either add up or subtract depending on direction.

If the cells are in parallel they will give the same PD as one but increased current flow.

Diode Circuits

If we consider a diode in a circuit it will share PD or other energy with components depending on the overall voltage as the resistance of the diode will change.

You can have several different circumstances. Simply treat them as new situations.

Solar Panels

Are made from a PN sandwich which means we can separate charged electrons and produce an **electric field**.

If a light **photon** through a glass screen falls onto our sandwich it releases the electrons to move through the field and produce an **electric current**.

This is how a solar cell works.

Diodes and AC

If you place a diode into a direct current circuit then it will conduct in a forwards direction.

However in an AC circuit will turn off the current in one direction and create half waves with missing half waves.

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Potential Divider

Simply divides the energy in a circuit but the current through the main circuit is constant.

Allows us to provide a variable PD to a component due to a change in condition i.e. pressure, temp, light, position

Pot Divider Formula

In the most basic form of a two resistor potential divider the current is the same throughout the circuit i.e. $\mathbf{V_s = IR}$. Then there is a V dropped over R_1 and R_2. The % drop across each is calculated by this formula which you must memorise.

$$V_2 = R_2 / (R_2 + R_1) \times V_s$$

This changes to R_1 on top for V_1.

Pot Div Issues

Voltage: Pot div circuit can provide the full range of voltage from V -> 0V, while a variable resistor circuit will not reach 0V.

Current: overall resistance is less as components in parallel so more current flows in the circuit and thus more energy is wasted.

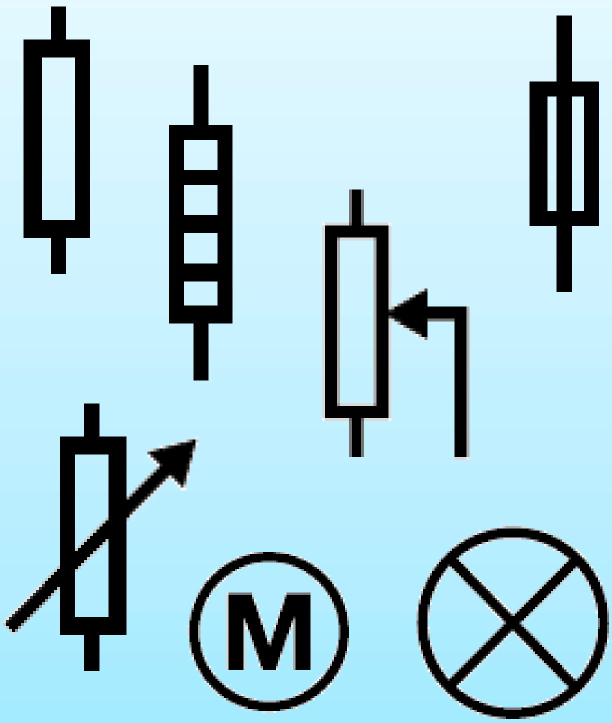
Pot Div Ratios V and R

We find that the energy splits up according the ratio of resistances so for R_1 and R_2....

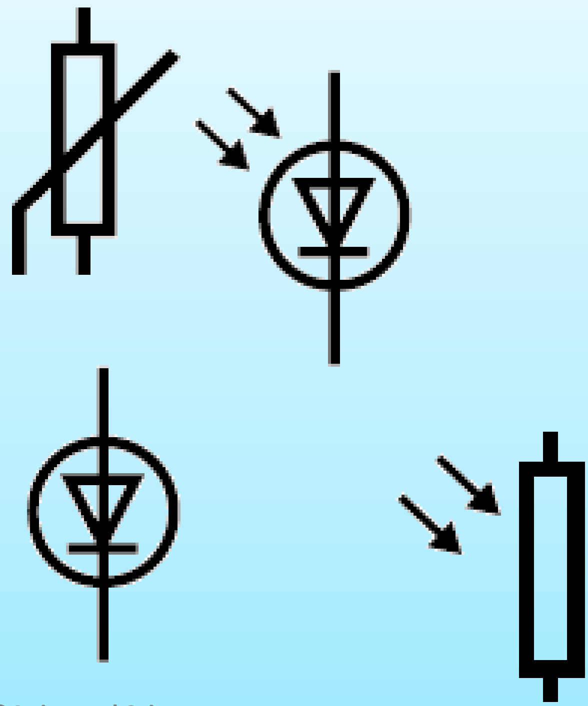
$$V_1/V_2 = R_1/R_2$$

This can be very useful if you don't have the current in a circuit and need a quick fire answer. But you have to memorise this one!

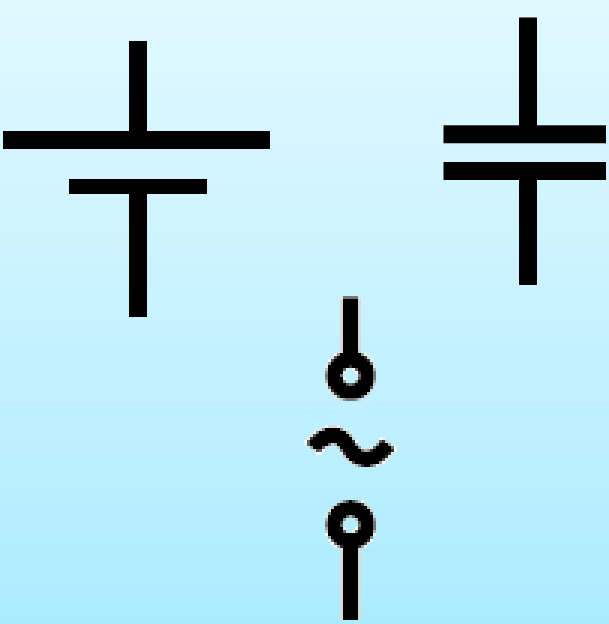
Resistances



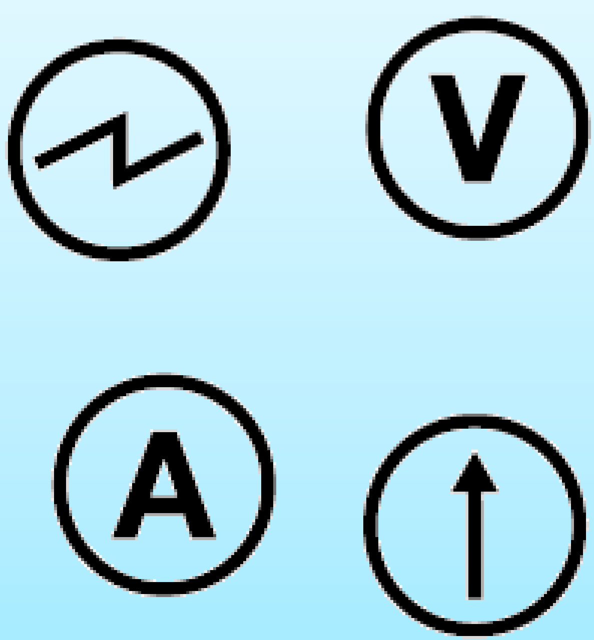
Funny ones!



Energy Sources



Meters



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